VIII. Utilities

A. Water systems

Water is commonly used as the medium for carrying excess heat away from power supplies and their loads in the Antiproton source. The most extensive water system found in Pbar is the 95° Low Conductivity Water (LCW) system which provides cooling for components in the Rings and Transport enclosures as well as the AP0, 10, 30 and 50 service buildings. LCW is water which has had free ions removed, increasing its resistance to electrical current. This attribute is critical if a device has cooling channels that also act as electrical conductors. Most rings and beamline magnets, for example, have hollow copper electrical windings that the LCW flows through. The Pbar 95° LCW system is not only used to cool most magnets and their power supplies, but also magnet shunts and TWT amplifiers used in the stochastic cooling systems.

The two heat exchangers, three pumps, de-ionizing (DI) equipment, deoxygenation skid and makeup reservoir for this system can all be found on the second floor (frequently referred to as the mezzanine) of the Central Utility Building (CUB). During normal operation, two of the three pumps are run which allows flexibility if a pump requires repair. Water flows through the deoxygenation skid and removes oxygen from the LCW that could combine with Copper to form CuO. Depending on the season, the LCW will pass through one or both of the two heat exchangers (both housed in a signal unit). The LCW heat exchanges with industrial water (also known as pond water) which originates from the Booster pond. The pond water passes through the base of CUB into the cooling water vault on the northeast corner of the building. After passing through a set of strainers the pond water is pumped to the various heat exchangers by four vertical pumps. During the warm weather months, when the pond water temperature is too high to provide sufficient (if any) cooling, the cooling towers atop CUB provide a supplemental drop in the temperature of the pond water before it passes through the heat exchangers. The cooling towers are like an automobile radiator in function but augmented by pond water flowing over the outside of the cooling fins to provide an additional temperature drop resulting from the latent heat of evaporation.

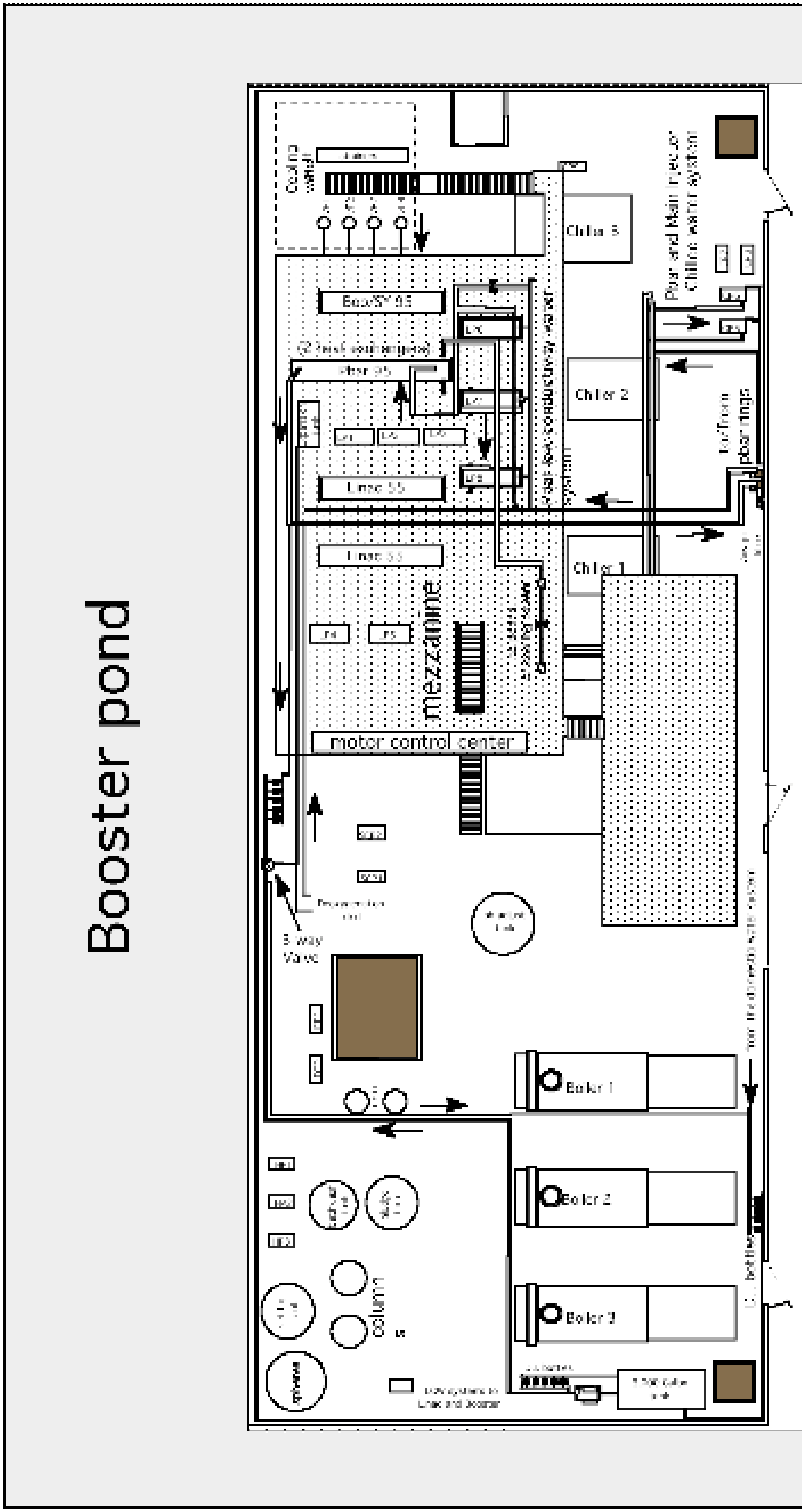

Figure 8.1 C... system

After water has returned from the heat loads in the tunnels and service buildings, it passes through one of two large “full-flow” filters in CUB. The primary motivation for adding this filter system, as well as the deoxygenation equipment already mentioned, is to minimize the production of CuO. Deposits of this copper oxide can line the inside of the magnet conductors and even cause blockages. The restricted water flow and insulated cooling channels results in elevated temperatures in the magnet. In extreme cases the magnet epoxy can be damaged and may lead to a magnet failure. A floor plan of CUB is provided in figure 8.1, which may be helpful in locating components of the LCW system.

The Chilled Water (CW) system, provides cooling water for the service building air conditioning units, the DRF1 cavities, and the stochastic cooling kicker tanks. It also removes heat from the closed loop LCW systems at AP0 and F27, which are described below. CW is pond water, which has been strained and chilled to approximately 48° Fahrenheit. The CW system is sometimes incorrectly referred to as the industrial chilled water system. This name tends to confuse CUB personnel as they use the CW designation for chilled water while referring to water in the fire hydrant network as Industrial Cold Water (ICW).

Tevatron 95° LCW flows through the AP1 and AP3 line magnets in the Pretarget and Prevault enclosures. Tevatron LCW is also used to cool power supplies at the F23 service building. LCW from the Tevatron system was used for reasons of convenience and economy.

Five closed loop, stand-alone LCW systems can be found at the perimeter of the Pbar complex. Each of these systems consist of a pump, heat exchanger, deionizer bottle, expansion tank, and associated plumbing and instrumentation, similar to the Linac water systems. CW is used to heat exchange with each closed loop LCW system. Four of the systems are located in AP0: one provides cooling for the collection lens, one for the beam dump, another for the pulsed magnet and a fourth for the proton lens. When needed, make up water to fill these systems is taken manually from the Pbar 95° LCW header nearby by target station technicians.

The other closed loop system is located at F27 and services the power supplies in that building. No LCW lines pass in the vicinity of the F27 building, hence the need for a separate system. When required, LCW at F27 is made up by the water group personnel from a 55-gallon drum of de-ionized water. As stated above, CW is the heat-exchanging medium and gets to F27 and AP0 by means of teeing off from the line that runs between CUB the RF building.

Important parameters of the water systems are monitored via ACNET and/or FIRUS. Temperature, pressure, oxygen level, turbidity and conductivity monitoring for the Pbar 95° LCW system can be found on page P75, a graphical display is also available on P74. Temperature and pressure readbacks for the chilled and pond (cooling) water loops can also be viewed from P75. In addition, the amount of water leaking out of the Pbar LCW system can be determined through the ACNET parameter D:LCWTOT. This device reads back the total amount of water made up over an arbitrary amount of time. The Pbar 95° LCW system has a 30 gallon reservoir which is filled up every time that amount of LCW has leaked out of the system. Under normal no-leak running conditions, 0 to 30 gallons per week is added to the system. A plot of D:LCWTOT would indicate 30-gallon increments at regular intervals if there were a leak (this parameter is reset to 0 gallons every day at midnight). D:LCWMUF monitors the flow into the makeup tank and normally reads zero. Only when the LCW system is automatically filling the 30-gallon reservoir should this parameter have a non-zero reading.

FIRUS also alarms if certain parameters are out of limits. In general, poor conductivity, incorrect pressures or tripped chillers or cooling towers should be brought to the attention of on-shift plant maintenance personnel i.e. the Duty Mechanic. Pressure or temperature alarms should be checked against their ACNET counterparts. Generally, the ACNET devices have more accurate alarm set points.

B. Vacuum systems

All of the beam lines and both rings are unique vacuum systems isolated from each other via vacuum windows (with the exception of the Accumulator to AP3 line connection). In all cases, distributed ion pumps provide most of the pumping and the vacuum chamber is broken into smaller segments with beam valves. A number of pump-out ports are built into the system to provide easy connection of mobile turbomolecular pump stations. Tevatron-style CIA crates are used to control the vacuum components. Beam valves are interlocked to close if three or more ion pumps in a section are tripped or indicate poor vacuum. Each system is outlined below. For the sake of clarification, Torr is normally the unit of measure used as a measure of vacuum although millibar (mbar) is the proper metric unit. The units are very similar in magnitude, average atmospheric pressure is 760 torr or 1,013 mb. Since the units are so close in magnitude, Torr and mbars can be used interchangeably.

Vacuum in the AP1 line is common to that of the Main Ring at F1 on the upstream end and AP3 on the downstream end. Beam valve M:BV100, located immediately downstream of the second (of two) 'C' magnets in that beam line, is interlocked to close if too many pumps trip in either the Main Ring or AP1. A vacuum window just inside of the target vault isolates AP1 from the target station. Beam Valve D:BV926 can isolate AP1 from AP3. The nominal AP1 line pressure of 10^{-8} mbar is maintained by distributed sputter ion pumps rated at 270 liters/second. Pump supplies and controls hardware for this system can be found in the AP0 building.

The target vault has no vacuum and serves as the break between AP1 and AP2 vacuum. Another window within the target vault isolates this line at its upstream end. AP2 vacuum is continuous to a window immediately upstream of the Debuncher injection septum magnet. Like AP1, the injection line vacuum is maintained through the use of distributed sputter ion pumps rated at 270 l/s. The nominal pressure of the beamline is 10^{-8} mbar.

The Debuncher, similarly, has its vacuum maintained with sputter ion pumps. The average Debuncher pressure is also 10^{-9} mbar. Beam valves at each '10' location can effectively subdivide the Debuncher into 6 separate vacuum sectors. Beam valve D:BV610 doubles as the safety system coasting beam stop for the Debuncher.

The D to A line is a stand alone vacuum system, the breaks being vacuum windows at the upstream end of the Debuncher injection septum magnet and the downstream end of the second Accumulator injection septum. Ion pumps keep this line's vacuum in the 10^{-8} mbar range.

Because the Accumulator was designed as a storage ring, its vacuum requirements are the most stringent. One of the significant terms in

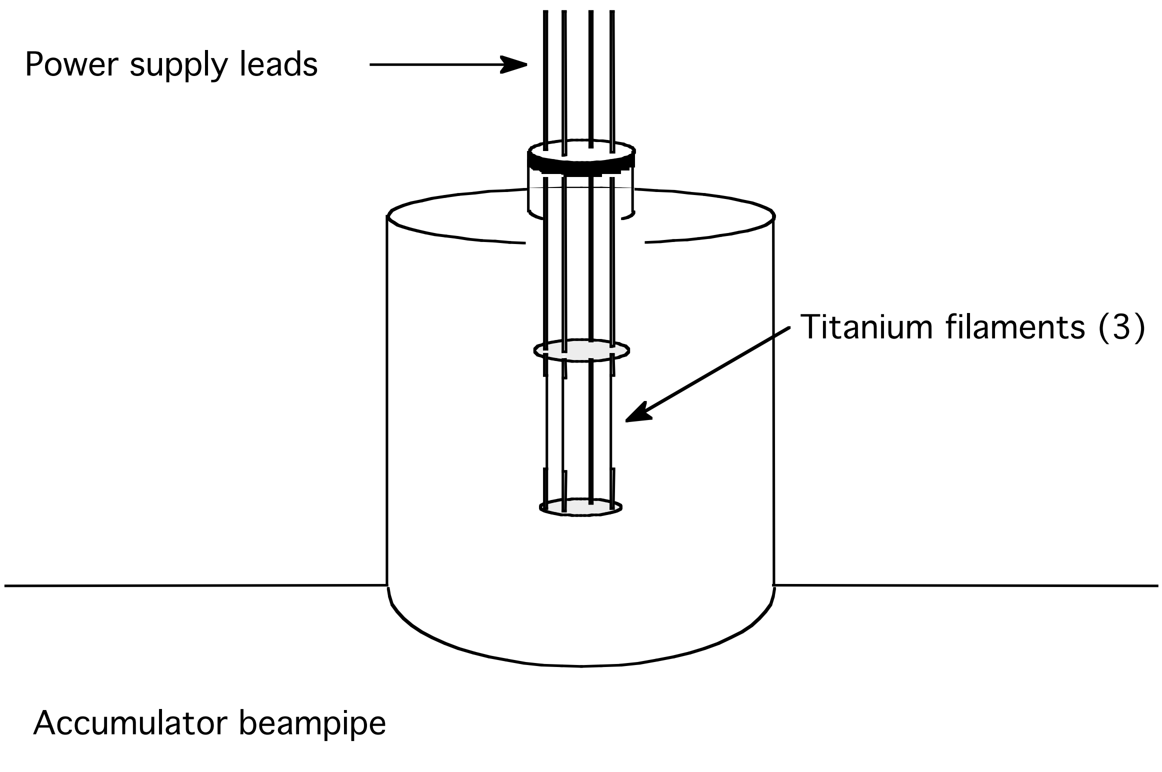

Figure 8.2 Titanium sublimation pump

determining the beam lifetime in a storage ring is the beam-gas interaction rate. Improving the vacuum lowers this interaction rate thereby reducing beam loss. The design pressure of the Accumulator is 3 X 10^{-10} Torr. This level is accomplished through the use of sputter ion pumps and titanium sublimation pumps supplemented by a bake-out system. As with the Debuncher, the Accumulator effectively has six vacuum sections. Beam valves in sectors 10 through 30 and 60 are found at the '7' locations. The valves for the 40 and 50 regions were moved from their original location to immediately upstream and downstream respectively of straight section 50. This provides isolation for the E835 hydrogen gas jet target and associated vacuum equipment with minimal impact on the Accumulator. This results in the Accumulator 40 and 50 vacuum section being larger than the others. Like D:BV610 in the Debuncher, beam valve A:BV607 acts as the safety system coasting beam stop for the Accumulator.

Titanium sublimation pumps are used for both the Accumulator and Recycler rings. The sublimation pumps are necessary to maintain the low vacuum required for both storage rings. Sublimation pumps are a form of getter pump which operate on the principle that chemically stable compounds are formed between gas molecules (H_2, N_2, O_2, CO, CO_2) and the getter (titanium). In this context, a getter is the material that gas molecules combine with to form stable compounds. Noble gases (such as helium) cannot be pumped by getters. A filament containing a high titanium content is heated resistively, the boiled off titanium forming a thin layer on the surrounding walls. For the Accumulator, the walls are adjacent to the beam pipe rather than being the beam pipe itself. As gas molecules impinge on the getter film, stable compounds are formed and the vacuum pressure improves since there are fewer gas molecules in the beam pipe volume.

Unlike ion pumps which are powered all of the time, the sublimation pumps in the Accumulator are powered infrequently. The sublimation pumps are "fired" over 90 seconds to sublimate approximately 10 monolayers of titanium onto the pump's interior surface. During normal operation, sublimations are spaced months apart. Each Accumulator sublimation pump contains 3 filaments to extend the lifetime of the pump, although only one filament at a time is sublimated (see figure 8.2). Because such pumps have no effect on inert gases, sputter ion pumps are still an integral factor in keeping the Accumulator vacuum at its best achievable level. To date, the best average vacuum in the Accumulator has been 6.8×10^{-11} Torr (as read by ion gauges); a typical value is 1.5×10^{-10} Torr.

A permanently installed bake-out system in the Accumulator makes it possible to bake each of the six sectors independently when conditions warrant. Usually when a portion of the Accumulator is let up to air, for installation of new diagnostics for example, a bake-out follows the work. Baking the beam pipe makes it possible to remove water vapor on the inner surface of the beam pipe and remove deep-seated impurities. Bake-out temperatures range from 130° C for stochastic cooling tanks to 250° C for quadrupoles. Pumping during a bake is by means of mobile turbomolecular pump carts. The bake is controlled by a single microprocessor in AP10 while an ACNET applications program exists for human interface. The processor receives inputs from thermocouples located in the tunnel and controls heaters to regulate the temperature. It typically requires several days to heat the components to the desired temperature, bake, then slowly cool back down to room temperature. Heaters and insulation coexist in the blankets, which are wrapped around the beam pipe and non-magnetic components. The magnets are not encased in blankets, rather, special channels for LCW together with heating elements are sandwiched between the beam pipe and magnets proper (see figure 8.3). Such an arrangement permits the beam pipe to be baked while minimal heat is imparted to the magnets.

The AP3 line vacuum is common to the Accumulator due to the concern that a vacuum window at the junction of the Accumulator and the beam line would cause unwanted transverse emittance blowup during beam transfer. Despite the absence of a vacuum window, Accumulator vacuum does not degrade significantly near the junction. A beam valve, BV900, provides protection in case of loss of vacuum in either the Accumulator or AP3 line. Vacuum is maintained in AP3 again with 270 l/s sputter ion pumps. The pressure is typically 10^{-8} mbar. Beam valve D:BV926 located in the Prevault enclosure provides isolation between the AP1 and AP3 lines.

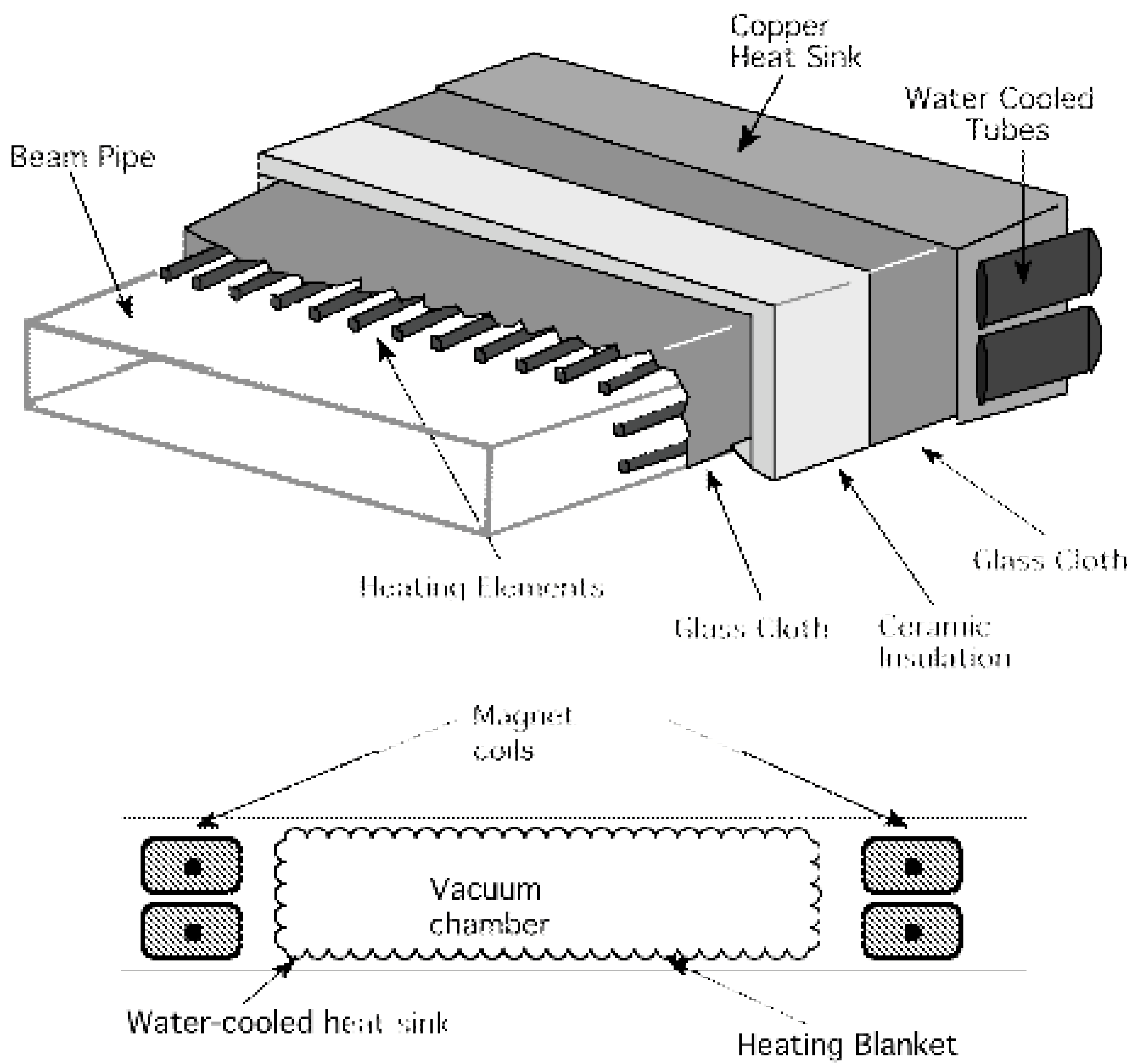

Figure 8.3 Accumulator dipole bakeout cross-section

C. Electrical systems

Power requirements for most of the Antiproton source complex is provided by feeder 24, a 13.8 kV feeder, which is the output of transformer 83A in the Master Substation. 13.8 kV is stepped down to 480 V in substations outside of AP0, 10, 30, 50, and F27. Breaker panels and additional transformers distribute power to all tunnel and house loads as well as nearly every power supply. The Debuncher and Accumulator bend bus supplies have separate outdoor transformers connected to feeder 24 at AP50 (see figure 8.4). Power for the AP1 line supplies, which are located at F23, comes from feeders 94/95, the beamline feeders. Also, some of the racks in the F27 service building are powered by a line from the F2 service building, which is connected to feeders

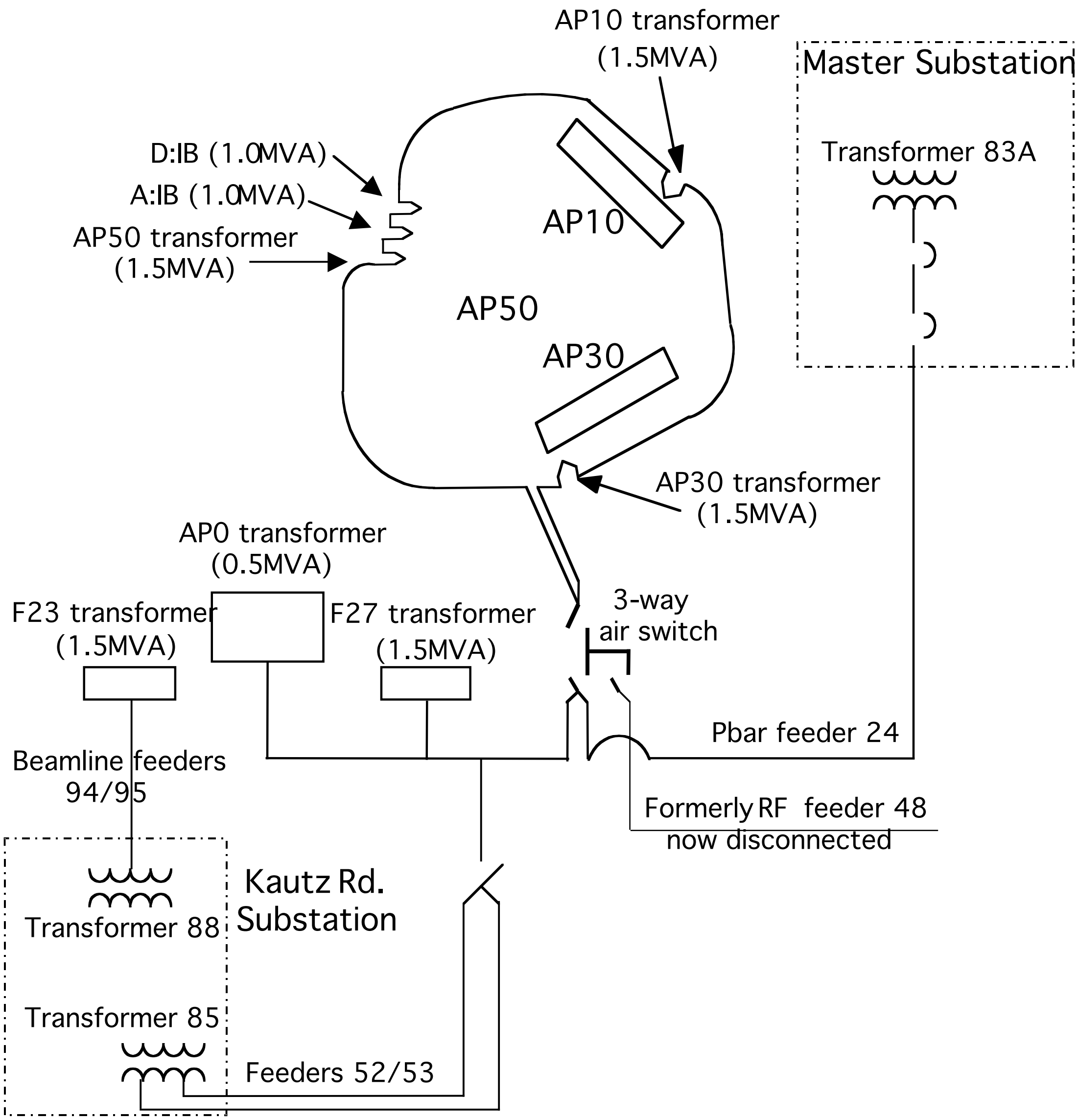

Figure 8.4 Antiproton source 13.8 kV feeder layout

94/95. The source can be powered by feeder 52/53, which powers Main Injector service buildings, by means of a transfer switch. This is not done during normal operation due that feeder's relative 'noisiness'. Normally, feeder 24's sole load (and transformer 83A) is the Pbar source.

In case of a power outage, an emergency diesel generator located at AP50 keeps Pbar source sump pumps, ventilation equipment, and the overhead crane in AP0 operational. If normal power is sensed to be absent at AP0, 10, 30, or 50 the generator is automatically turned on and the emergency feeder energized. Meanwhile, a transfer switch in or below the building(s) sensed to be without power switches in the emergency feeder. The generator is automatically tested every week. Controls for the generator is located at AP0.

D. Cryogenic systems

Liquid helium is used to cool the pickup electrodes and GaAsFET amplifiers of the Debuncher betatron and momentum systems. Similarly, liquid nitrogen is used on pickups for the stacktail and core 2-4 GHz momentum-cooling systems. By reducing the temperature of these components, the electronic noise they generate is greatly reduced. Electronic noise scales linearly with absolute temperature so there is a considerable reduction in the noise level. This is primarily a concern with the stacktail and Debuncher cooling systems, which operate on low intensity beams. Pickups for the core systems detect a much larger signal due to the larger beam intensity. The core 2-4 GHz momentum cooling system makes use of liquid nitrogen only because the pickup tank is located in A20 next to the stacktail pickups. Performance of the system is only improved by a small amount, but little additional hardware was required to provide liquid nitrogen to the tank.

Cryogenics are provided to these areas by means of transfer lines traveling above ground from AP30 to the D10 and A60 regions, thence through penetrations into the tunnel. AP30 houses a satellite refrigerator once used to provide liquid helium to fill three Dewars that contained stacktail momentum cooling notch filter components. This refrigerator is now relegated to a test set up for the Cryogenics department. The AP30 refrigerator is connected to the Tevatron cryogenic system via helium and nitrogen lines between it and the F3 refrigerator building.

E835 uses liquid nitrogen for a cold trap for the gas jet target. A flexible hose transfer line inside of the Rings enclosure transports lN_2 from A60 to the A50 straight section. The experiment also has a "stand alone" helium system housed in the AP50 service building. Helium is transferred through a buried pipe between AP30 and AP50. After passing through the refrigerator in the AP50 service building, the helium passes downward to a cryostat in the A50 experimental pit. The helium is used to reduce electronic noise on the E835 VLPC (Visible Light Projection Chamber).

Control for the majority of the pbar cryogenic systems is identical to that of the Tevatron and Switchyard refrigerators. The house names for the three microprocessors servicing Pbar are: 'PR' for the Pbar Refrigerator equipment at AP30, 'P1' for the area 10 and 60 loops, and 'P3' for the lines leading to the lHe Dewars at AP30 that are no longer used. Feedback loops manipulate valves to control each stochastic cooling tank's temperature. The helium system in AP-50 was developed by the old Research Division and uses a different controls interface.

E. Controls system

As with other accelerators on site, the pbar source is controlled and monitored from the Main Control Room via ACNET consoles which send and receive information by means of the Accelerator Division's VAX cluster, known as ALMOND, and the Pbar VME type front end computer. A dedicated serial link connects all of the service buildings, including F23 and F27, with the Pbar front end. In actuality there are six serial loops: PIOX, TCLK, PIOR BTR, MRBS, Pbar Beam Permit Loop, and a link for remote ACNET consoles.

The pbar CAMAC link is connected within and between service buildings with repeaters (figure 8.5 shows the layout of the crates and repeaters in the service buildings). An Applications program currently residing on D20 visually displays the status of the link and the contents of each crate. The pbar controls system is unique in the number of diagnostic devices such as spectrum analyzers, which can be controlled and displayed remotely. This is made possible through the use of the GPIB protocol. GPIB is an acronym for General Purpose Interface Bus and is based on HPIB developed by Hewlett-Packard.

Crates are numbered according to the service building they are located in. AP10 houses the $1n crates, the 30 and 50 houses contain the $3n and $5n crates respectively. Crates $70 through $74 are located in AP0, $80-$82 in F23, and $90 and $91 in F27 (see figure 8.5). Not all pbar source devices are controlled through the pbar front end, it is sometimes more convenient to control devices from nearby CAMAC crates attached to a different front end. For example, pbar LCW parameters from CUB are read back through the Booster front-end.

The source has a dedicated beam permit/abort loop. The Pbar Beam Permit Loop is a serial loop of CAMAC 200 modules which is sourced in the MCR back racks in a unique 201 card. The 201 sends out a 5 MHz signal, which, if each 200 module has no faults, is passed along and returned to the 201. If one of the eight inputs to a 200 module is low, the 5 MHz signal is not passed along and the loop collapses. There is no beam dump in the Rings into which beam can be aborted. The Beam Switch Sum Box (BSSB) in the Main Control Room will not allow beam to Pbar if the permit is down. The Main Injector Beam Synch (MIBS) event associated with extraction from the Main Injector to pbar will also be disabled if the pbar permit is down. Only a limited number of devices will pull down the permit loop. These inputs included the Rings and Transport radiation safety systems, E835 radiation monitors, the F17 Lambertson power supplies and a summation of radiation monitors (chipmunks) located in the antiproton source service buildings.

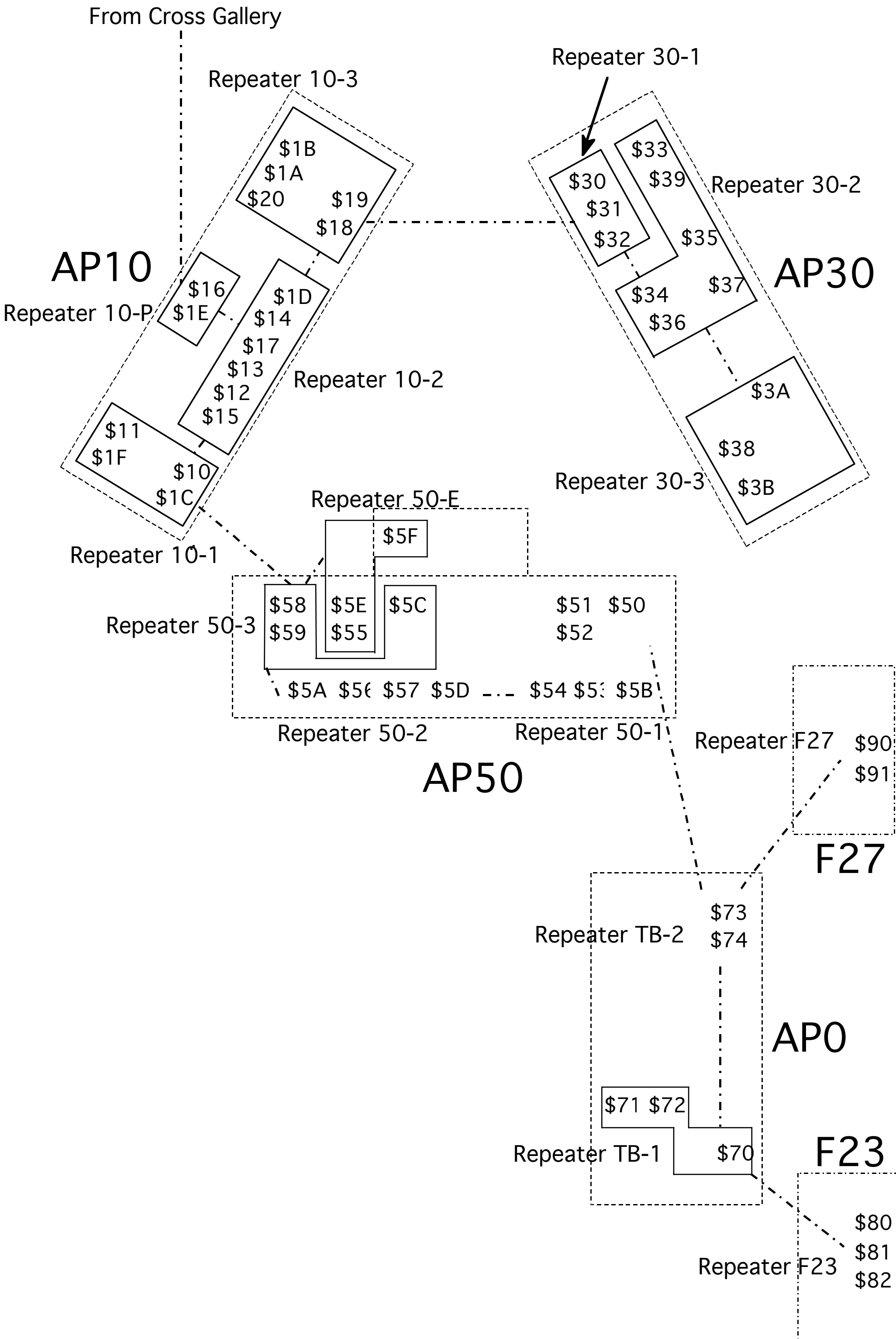

Figure 8.5 Pbar Source CAMAC Serial Link